

WHAT IS CLAIMED IS:

1. An optical device comprising:
a semiconductor substrate; and
an optical part having a plurality of columnar members
disposed on the substrate,

wherein each columnar member is disposed in a standing manner
and adhered each other so that the optical part is provided, and
wherein the optical part is integrated with the substrate.

2. The device according to claim 1,
wherein the semiconductor substrate is made of silicon, and
wherein the optical part is made of silicon oxide.

3. The device according to claim 1,
wherein the optical part includes a lower part, which connect
to the substrate, and

wherein the lower part has a concavity and convexity, which
aligns periodically in a horizontal direction parallel to the
substrate.

4. The device according to claim 1,
wherein the optical part includes a micro lens array.

5. The device according to claim 1,
wherein the optical part includes a light guide.

6. The device according to claim 4,

wherein the optical part further includes a slit and a light guide.

7. The device according to claim 1,
wherein each columnar member has a boundary disposed therebetween, and

wherein the boundary is parallel to a light axis of the optical part.

8. The device according to claim 1, further comprising:
a connection portion disposed between the substrate and the optical part,

wherein the connection portion includes an upper part,
wherein the upper part has a concavity and convexity, which aligns periodically in the horizontal direction parallel to the substrate,

wherein the concavity and convexity of the connection portion connects to the concavity and convexity of the optical part, and

wherein the connection portion includes a lower part, which connects to the substrate.

9. The device according to claim 1,
wherein the substrate includes a concavity, and
wherein the optical part is disposed in the concavity with a clearance.

10. The device according to claim 1,

wherein the optical part has a thickness in a vertical direction, which is perpendicular to the substrate, and wherein the thickness is equal to or larger than $10\mu\text{m}$.

11. The device according to claim 1, wherein the columnar member includes two part, wherein one of the columnar member is formed by deposition, and the other is formed by thermal oxidation.

12. The device according to claim 1, wherein the optical part includes an impurity doped layer, and wherein the impurity doped layer has an impurity concentration distribution in a vertical direction of the substrate.

13. The device according to claim 12, wherein the impurity concentration distribution has a chevron shape so that a maximum impurity concentration is disposed in a predetermined depth, which is measured from a surface of the optical part.

14. The device according to claim 12, wherein the impurity doped layer has an impurity including germanium, phosphorous, tin and boron.

15. The device according to claim 3, further comprising: a lens disposed on the substrate,

wherein the lens is a separate part and different from the substrate, and

wherein the lens is optically connected to the micro lens array.

16. The device according to claim 15,

wherein the micro lens array condenses or collimates a light in a horizontal direction, which is parallel to the substrate, and

wherein the lens condenses or collimates the light in a vertical direction, which is perpendicular to the substrate.

17. The device according to claim 3, further comprising:

an actuator disposed on the substrate,

wherein the micro lens array has a light axis, and

wherein the actuator oscillates the micro lens array in a horizontal direction so that the micro lens array scans a light in the horizontal direction, which is perpendicular to the light axis.

18. The device according to claim 17,

wherein the micro lens array is a plano-convex lens so that the light entered into the micro lens array is shifted its light path from the light axis of the micro lens array so as to output the light in a different direction.

19. The device according to claim 1,

wherein the micro lens array is a plano-convex lens, a plano-concave lens, a biconvex lens, a biconcave lens, and a meniscus

lens.

20. A method for manufacturing an optical device, comprising the steps of:

etching a semiconductor substrate with a predetermined mask so that a plurality of trenches is formed in the substrate and a plurality of semiconductor wall is formed between the trenches; and

thermally oxidizing the substrate so that the semiconductor wall is transformed into a semiconductor oxide wall and the trench is filled with semiconductor oxide,

wherein the semiconductor oxide wall and the semiconductor oxide in the trench provide an optical part, and

wherein the optical part is integrally formed with the substrate, and passes a light therethrough.

21. The device according to claim 20,

wherein the semiconductor substrate is made of silicon, and the semiconductor wall is made of silicon, and

wherein the optical part is made of silicon oxide,

wherein the semiconductor oxide wall and the semiconductor oxide in the trench are adhered together in the step of thermally oxidizing the substrate.

22. The method according to claim 20,

wherein the trench has a width, and the semiconductor wall has another width, and

wherein the widths of both of the trench and the semiconductor

wall are determined in such a manner that the trench is filled with the semiconductor oxide and at the same time the semiconductor wall is transformed into the semiconductor oxide wall in the step of thermally oxidizing the substrate.

23. The method according to claim 22,
wherein a ratio between the width of the trench and the width of the semiconductor wall is 0.55:0.45.

24. The method according to claim 20,
wherein a plurality of trenches and semiconductor walls provide an optical-part-to-be-formed region,

wherein the trench further includes an outside trench, and the semiconductor wall further includes an outside semiconductor wall, and

wherein the optical-part-to-be-formed region is surrounded with the outside trench so that the outside semiconductor wall is disposed on an outmost periphery of the optical-part-to-be-formed region.

25. The method according to claim 24,
wherein the optical-part-to-be-formed region includes a plurality of trenches and semiconductor walls, each of which is parallel each other and disposed alternately so that the optical part becomes a plano-convex lens, a plano-concave lens, a biconvex lens, a biconcave lens, and a meniscus lens.

26. The method according to claim 24,
wherein the outside semiconductor wall has a width being equal to or smaller than that of the semiconductor wall disposed between the trenches.

27. The method according to claim 24,
wherein the outside trench has a sufficient width so that the outside trench has a clearance after the semiconductor oxide is formed on a sidewall of the outside trench in the step of thermally oxidizing the substrate.

28. The method according to claim 20,
wherein each trench is parallel to an optical axis of the optical part.

29. The method according to claim 20,
wherein the step of etching the substrate including the steps of:

etching the substrate with using reactive ion etching method so that an initial trench is formed;

forming a passivation oxide film in an inner wall of the initial trench;

etching the passivation oxide film disposed on a bottom of the initial trench; and

etching the bottom of the initial trench with using the reactive ion etching method so that a final trench having a high aspect ratio is formed.

30. The method according to claim 20,
wherein the optical part includes at least one of a lens, a light guide or a slit so that the optical part is integrally formed with the substrate.

31. The method according to claim 20,
wherein the step of thermally oxidizing the substrate further includes the step of:

depositing a semiconductor oxide film in a clearance in the trench in a case where the trench has the clearance after the semiconductor oxide is formed on a sidewall of the trench in the step of thermally oxidizing the substrate.

32. The method according to claim 20, further comprising the step of:

forming an epitaxial layer on the substrate,
wherein the epitaxial layer includes an impurity concentration distribution having a chevron shape in a film thickness direction.

33. The method according to claim 32,
wherein the optical part includes the epitaxial layer so that the optical part condenses a light in a vertical direction, which is perpendicular to the substrate.

34. The method according to claim 20, further comprising the step of:

implanting an impurity on the substrate so that an impurity doped layer is formed,

wherein the impurity doped layer includes an impurity concentration distribution having a chevron shape in a film thickness direction.

35. The method according to claim 20, further comprising the step of:

annealing the substrate in a dopant atmosphere so that an impurity doped layer is formed,

wherein the impurity doped layer includes an impurity concentration distribution having a chevron shape in a film thickness direction.

36. The method according to claim 27,

wherein the epitaxial layer includes germanium, phosphorous, tin or boron as an impurity.